Initial Development of a UV Spectroscopy Endstation on ALS Bend Magnet 1.4 for the Investigation of Wide Bandgap Semiconductors

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INTRODUCTION

This project (duration = 6 months, $90k funding) encompassed the construction of a new endstation on ALS beamline 1.4 to perform spectroscopy in the ultraviolet (UV) area of the spectrum. By exploiting the high brightness and directionality of the bend magnet radiation, it is possible to make an intense, versatile source for spectroscopic studies in the 180 nm - 350 nm range. The source characteristics were measured and initial spectroscopic experiments were performed with semiconducting films of the III-V nitride family: InN (E_g = 1.9 eV), GaN (E_g = 3.4 eV), AlN (E_g = 6.1 eV) and their alloys. We chose this materials system because there is intense scientific interest in this materials system due to the recent commercialization of high efficiency blue and green LEDs and the demonstration of blue cw laser operation.

RESULTS AND DISCUSSION

Beamline construction and source characterization. A new experimental hutch was constructed (1.4.1) and the requisite laser table and optics were installed. The source strength at the laser table was in good agreement with bend magnet calculations provided by the ALS Systems group. The total cw power at 350 mA ring current is 50 mW broadband at the UHV exit window. After beam shaping and diversion, the power is still 20 mW at the laser table. It was also shown that the beam could be focused without intensity loss to 100 μm and smaller spot sizes; this capability will be useful for studies with small samples. Figure 1 shows the results of a

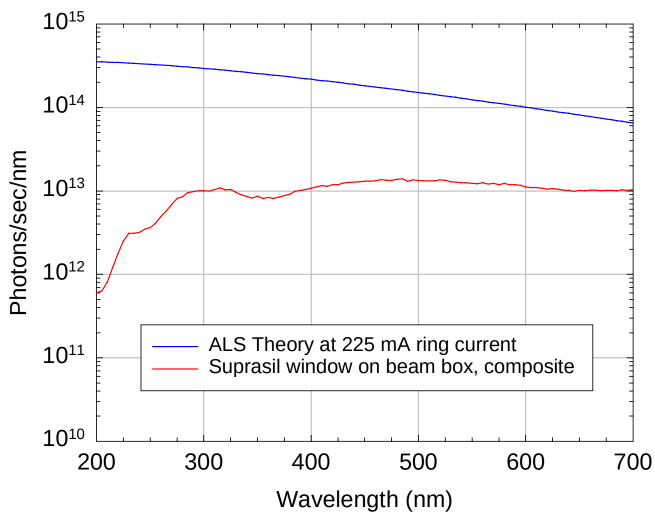

Fig. 1. Absolute source strength measured at Beamline 1.4.1. UV light was focused by 200 mm fused silica lens onto the entrance slit of a single 0.5 m monochromator (slit width = 350 microns, 1.4 nm bandwidth). The light was detected with PMT and the absolute calibration was performed with a NIST-traceable standard of irradiance. Plotted data is a composite of overlapping scans optimized for maximum throughput at 200, 225, 300, and 500 nm.

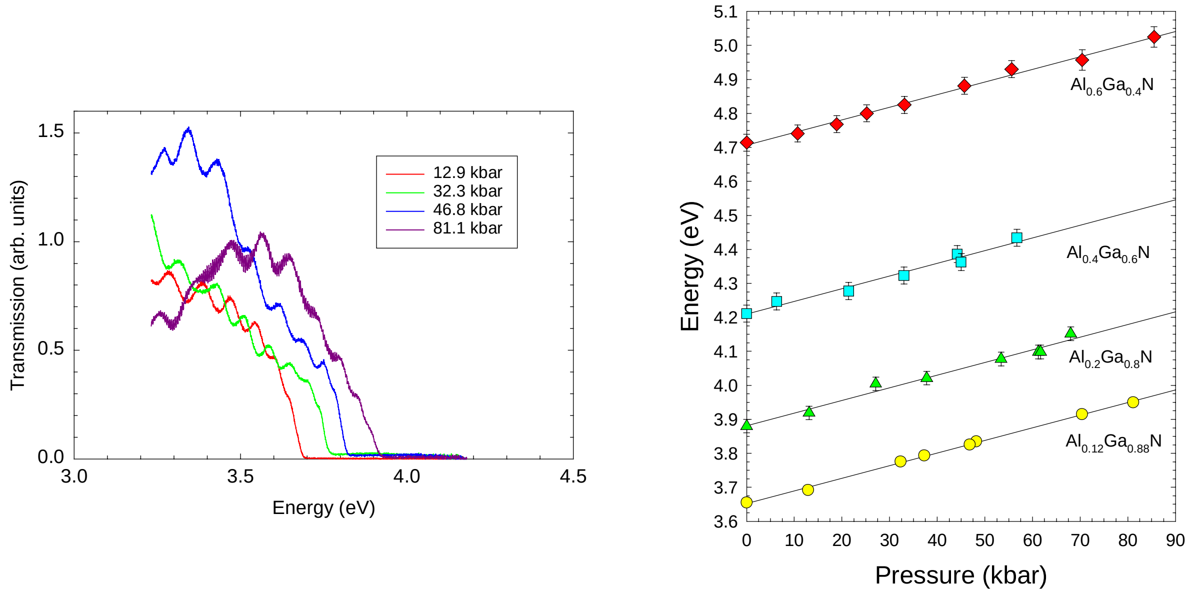

Figure 2. Left: absorption spectra of an AlGaN epitaxial film obtained as function of pressure in a diamond anvil cell. Focused UV light from Beamline 1.4.3 of the Advanced Light Source was used as the UV light source. Bottom: pressure dependence of the fundamental gap of AlGaN samples obtained from UV absorption measurements at the ALS.

measurement of the absolute source strength measured at the laser table.

Pressure dependence of AlGaN bandgap. The pressure dependence the band gap of a series of $Al_xGa_{1-x}N$ epitaxial films was measured. The bandgap was determined by optical absorption; pressure was applied with a diamond anvil cell (DAC). This experiment is difficult to perform with conventional UV sources because of the small size of the samples (ca. 200 µm in diameter). However, the superior collimation of the ALS source enabled the UV beam to be focused precisely on the sample in the cell. A spectrometer and CCD camera were used to obtain the absorption spectra (Fig. 2, top). The pressure dependence of the band gap of these alloys is being used to understand the band structure of III-V nitrides.

Photoluminescence in InGaN quantum wells. Photoluminescence (PL) measurements were performed in InGaN quantum wells at 77 K. A 0.25 m monochromator was used to select the excitation wavelength, which was varied from 300 nm (4.13 eV) to 350 nm (3.54 eV). The

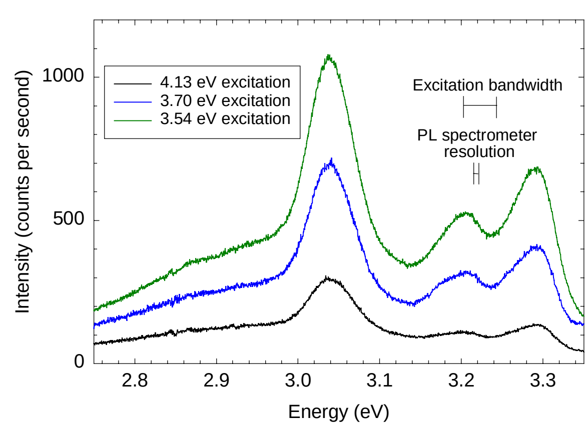

Figure 3. Photoluminescence spectra of $In_{0.15}Ga_{0.85}N$ quantum wells excited by UV light from Beamline 1.4.3, Advanced Light Source. The peak at 3.05 eV is from the quantum well. The peaks at 3.28 and 3.21 eV are donor-acceptor pair recombination and the LO phonon replica in GaN, respectively. The PL intensity decreases with excitation wavelength due to a reduced absorption depth in the 200 nm GaN cladding layer.

results are shown in Fig. 3. Very little PL was observed for excitation energies below 3.5 eV, the band gap of GaN. This demonstrates the that the PL from the InGaN quantum wells originates from electrons diffusing from the GaN cladding layer to the well, rather than from direct excitation of carriers in the quantum well. This experiment demonstrates that Beamline 1.4.1 can generate sufficiently bright, tunable, UV light for investigation of III-V semiconductors.

FUTURE WORK

We are currently constructing an experiment to perform temperature-dependence measurements of absolute reflectivity of manganites in collaboration with J. Orenstein of the Materials Sciences Division.

PUBLICATIONS

J. W. Ager III, W. Shan, K. M. Yu, W. Walukiewicz, E. E. Haller, M.C. Martin, W. McKinney, and W. Yang, "Pressure dependence of the fundamental energy band gap of AlGaN alloys," *J. Appl. Phys*., in press.

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